

The Waterfall Model – What It Is Not and Has Never Been

May 18, 2012

Peter Hantos
Software Acquisition and Process Department
Software Engineering Subdivision

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245-2808

Authorized by: Senior Vice President, Engineering and Technology Group

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Leslie J. Holloway, Department Director
Software Acquisition and Process
Department
Computers and Software Division
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Dr. Peter Hantos
The Aerospace Corporation

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Outline

- Motivation
- Parsing the Title
- The Canonical Waterfall Model
- Model Characterization
- What Does the Waterfall Life Cycle Really Look Like?
- Clarifying the Model's Intent
- “Hidden” Concurrency in the Waterfall
- Incremental Integration and Pair-wise Testing
- Scaling
- Conclusion
- Acronyms
- References



Motivation

- Your first reaction might be “Why are we talking about the waterfall? I thought that the Waterfall was dead”
 - *Indeed, since the Waterfall model was published, the literature has been full with critiques and proposals for alternative processes, most recently Agile Development*
- However, a substantial percentage of waterfall project failures can be attributed to lack of understanding of some fundamental issues, issues that are also present when modern methodologies are used
 - *Ignoring such issues will lead to project failure, regardless of the methodology that is used*
- Also, the waterfall (or, a “mini” waterfall) is still an essential building block of all the more complex life cycle models, such as incremental, evolutionary, spiral, or iterative incremental development (IID)



Parsing the Title-1: “Waterfall” is a metaphor



Glade Creek Spring Waterfalls



Parsing the Title-2: Model

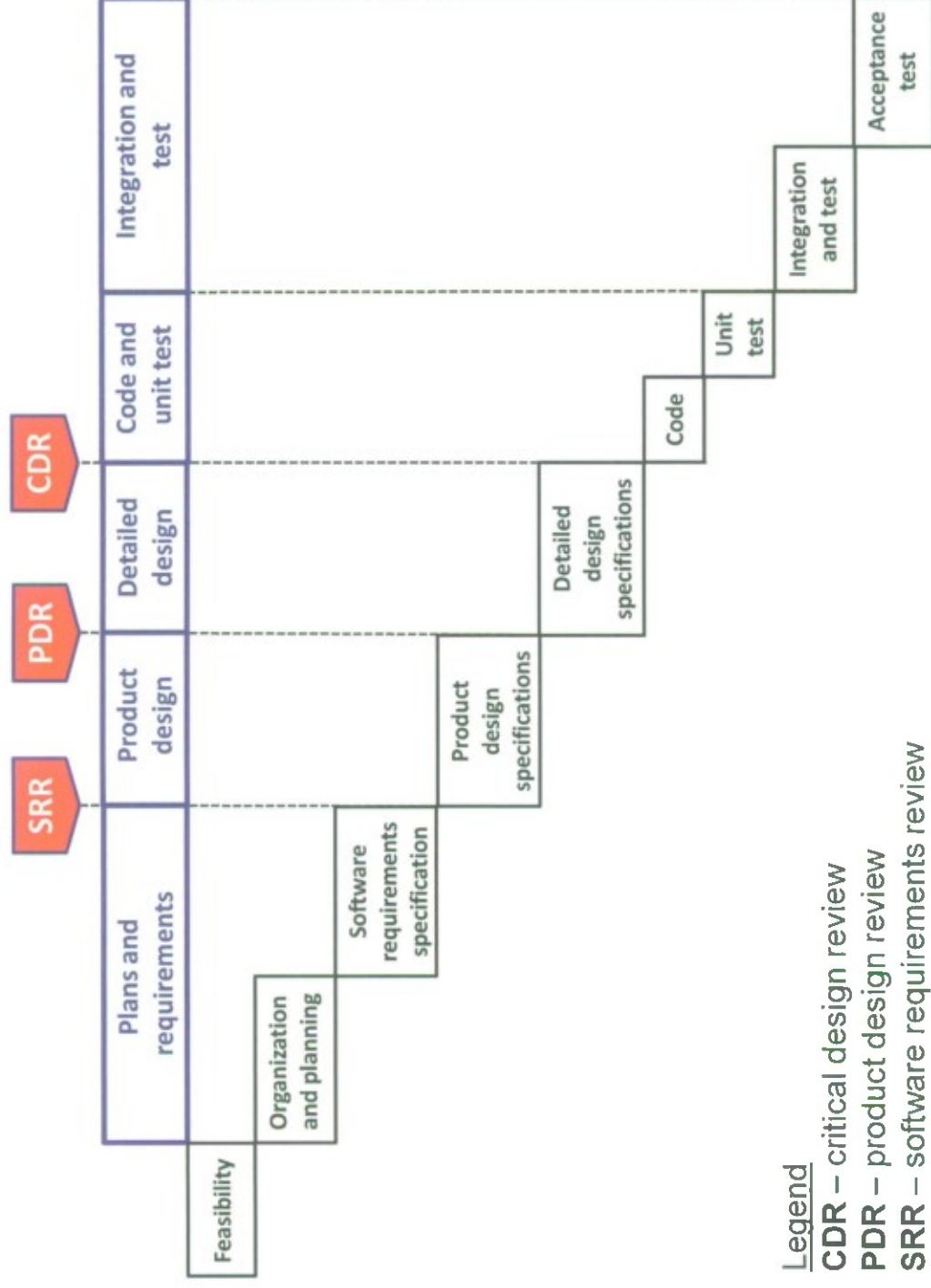
- Definition of a model*
 - A model is always a reproduction of an original system
 - However, a model is an abstraction and does not reproduce all attributes of the original system
 - Models serve a certain purpose and they are to be used in a certain context
- What we are going to do
 - Start with the prevailing description of the Waterfall Model
 - Highlight the hidden abstractions of the model
 - Develop successively more complex descriptions to facilitate the understanding of underlying issues

All models are wrong. Some models are useful.
~~~ George Box

\* [Stachowiak 1973]



# The Canonical Waterfall Model\*



## Legend

**CDR** – critical design review

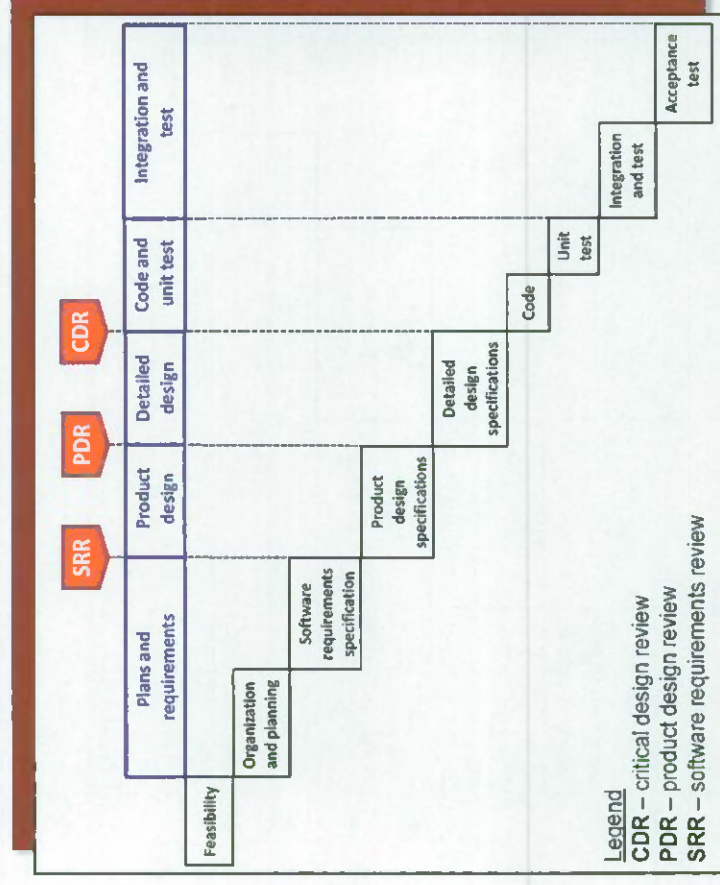
**PDR** – product design review

**SRR** – software requirements review

\* [Boehm 1981]



# Model Characterization

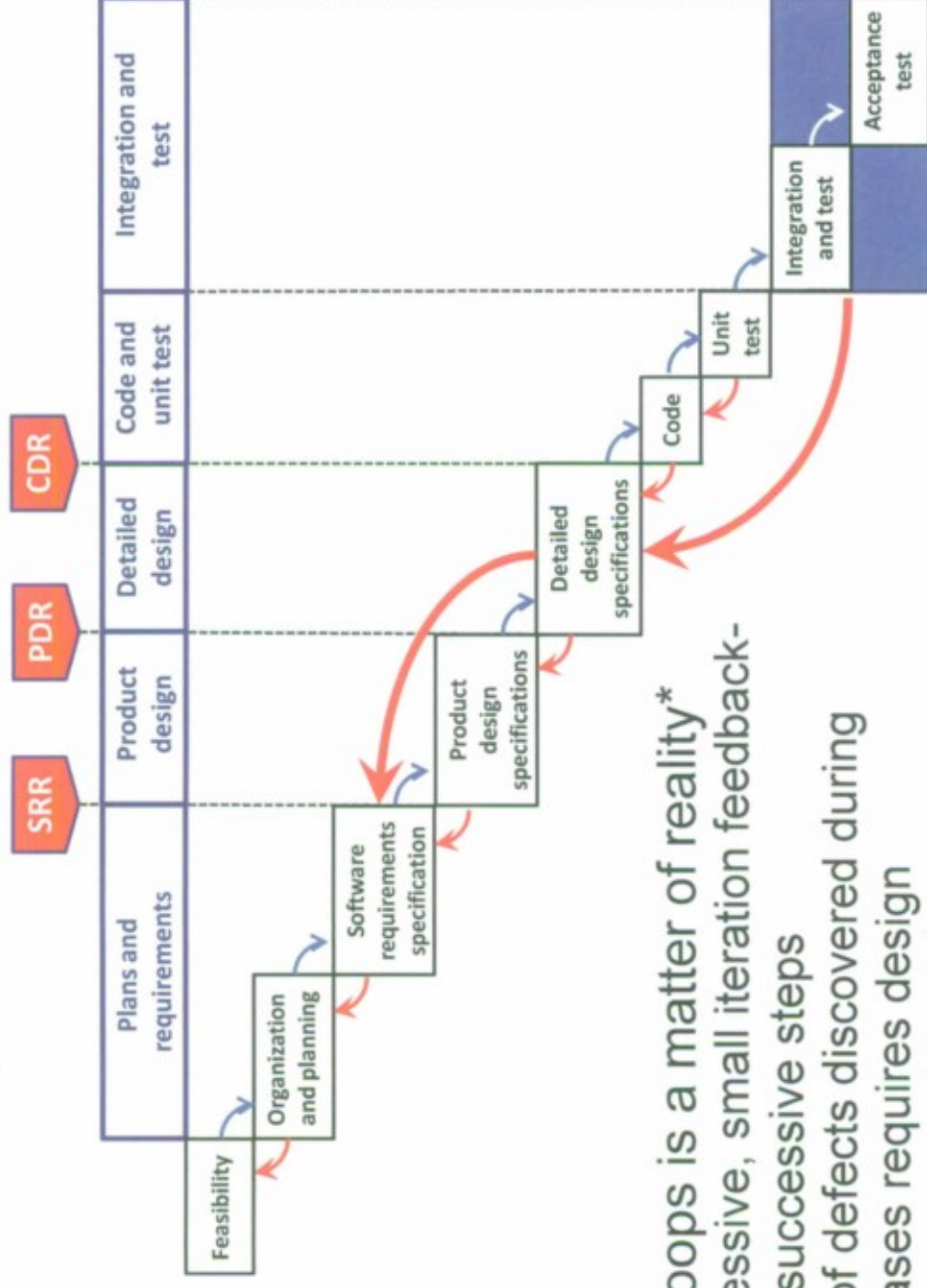


- Scaling: **No**
  - Seems to depict a macro view of software development
- Depiction of feedback loops: **No**
- Depiction of concurrency: **No**
- Presence of other technical disciplines: **No**
  - The “product” is software only





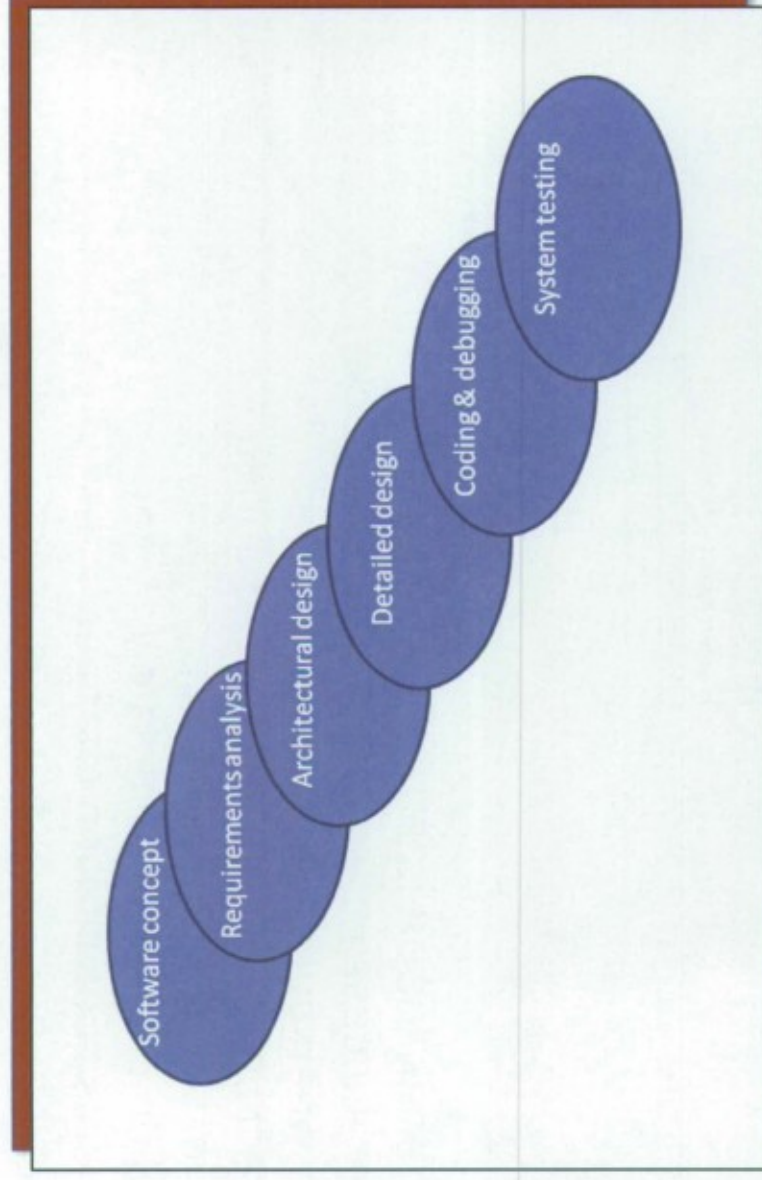
# Hidden Feedback Loops



- Having feedback loops is a matter of reality\*
  - There are successive, small iteration feedback-loops between successive steps
  - The correction of defects discovered during the final test phases requires design specification changes or ultimately, requirements specification changes
  - The basic interpretation of the metaphor (one-directional flow) needs to be challenged

\* Based on [Royce 1970]

## Phase Overlap Added – the Sashimi Model\*

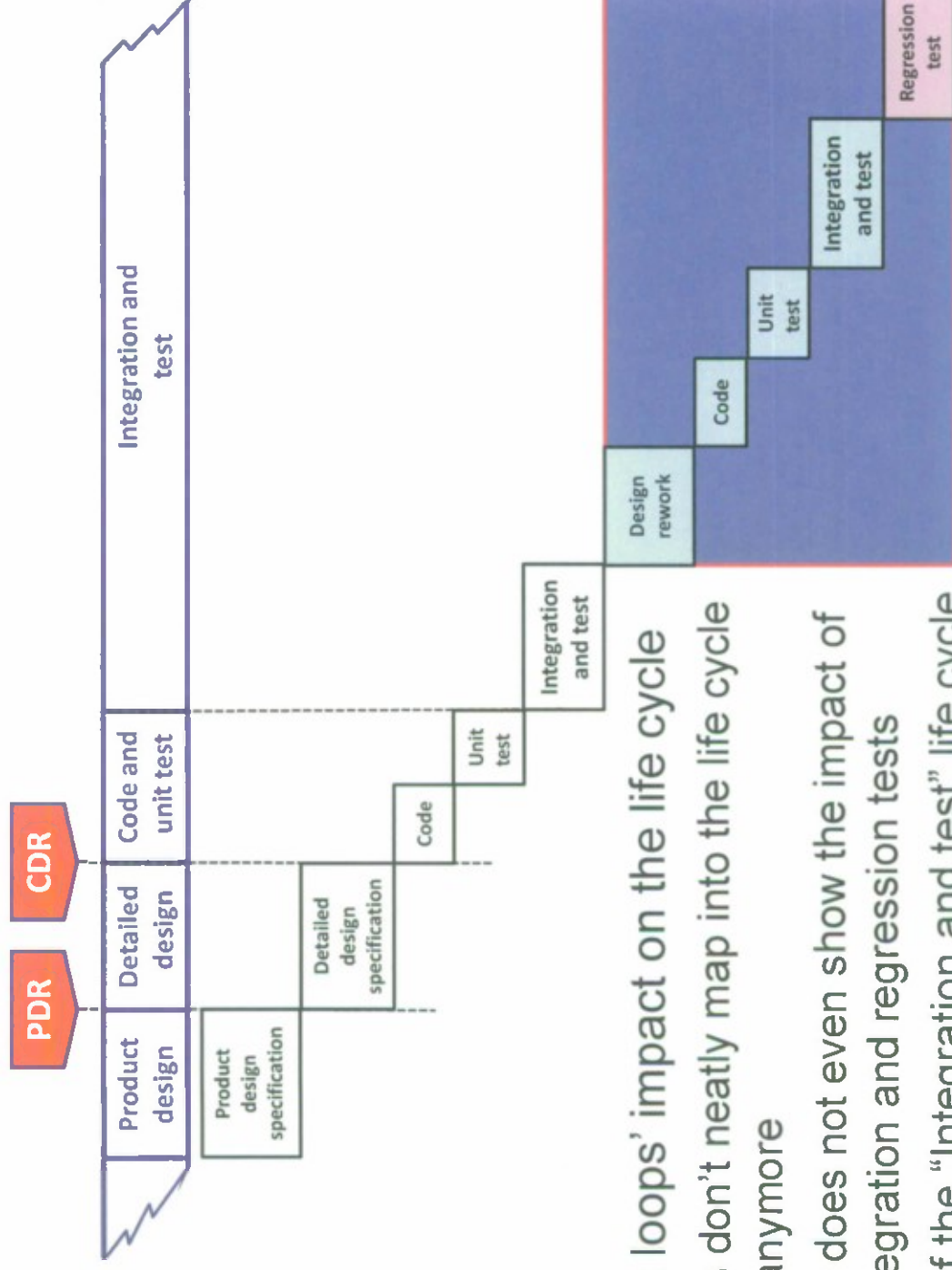


- Overlap is suggested between phases
  - This overlap can reduce belated problem discovery
- However, in most cases this is not really concurrency but iteration
  - Correcting design while coding is essentially iteration
  - It was shown earlier that to deal with defects such small-scale iteration is inherently present in the Waterfall model

\* Source: [McConnell 1996]. Note his slightly more up-to-date terminology.



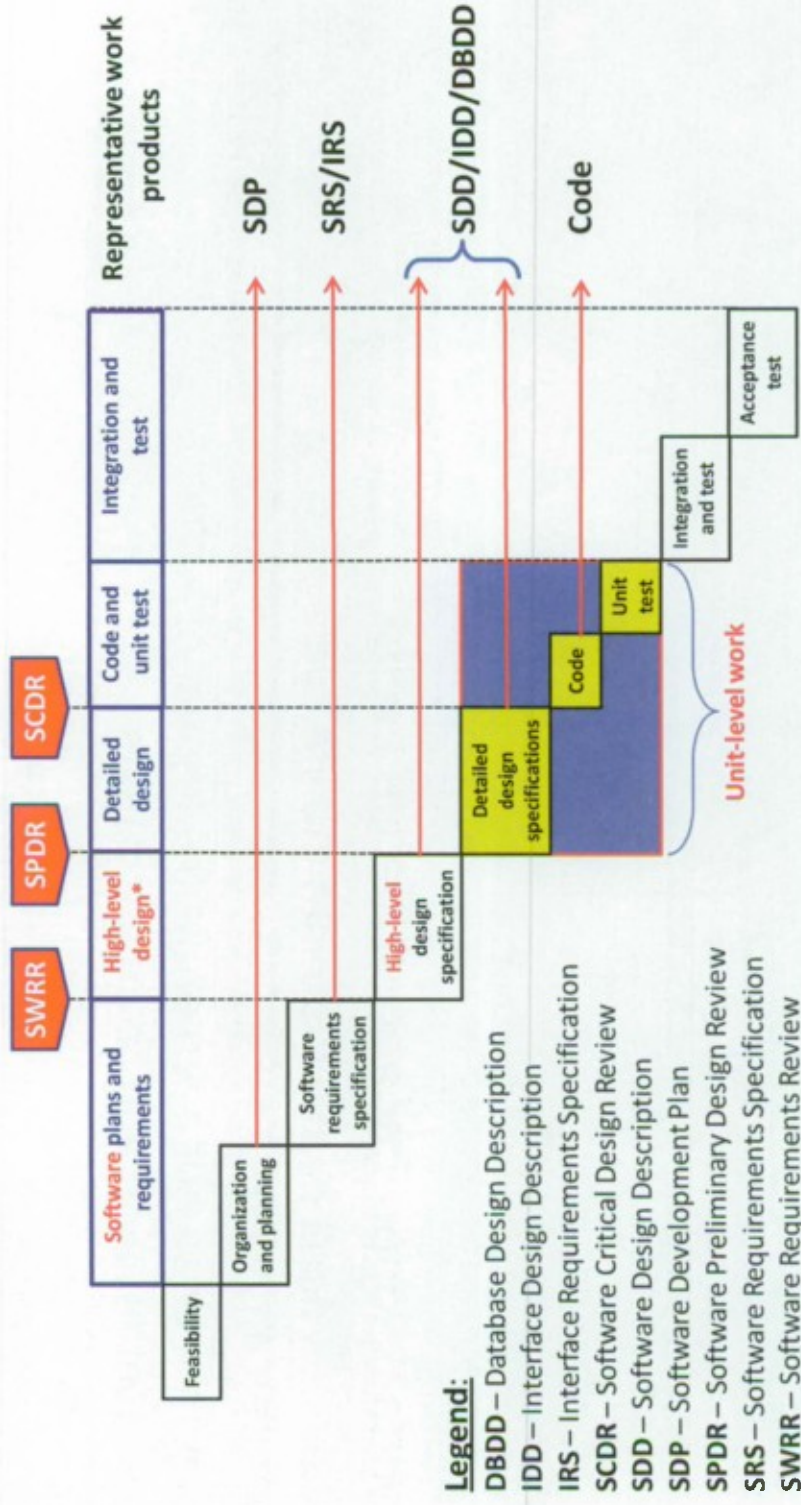
# What Does the Waterfall Life Cycle Really Look Like?



- Feedback loops' impact on the life cycle
  - Activities don't neatly map into the life cycle phases anymore
  - Diagram does not even show the impact of failed integration and regression tests
  - Length of the "Integration and test" life cycle phase is becoming more uncertain



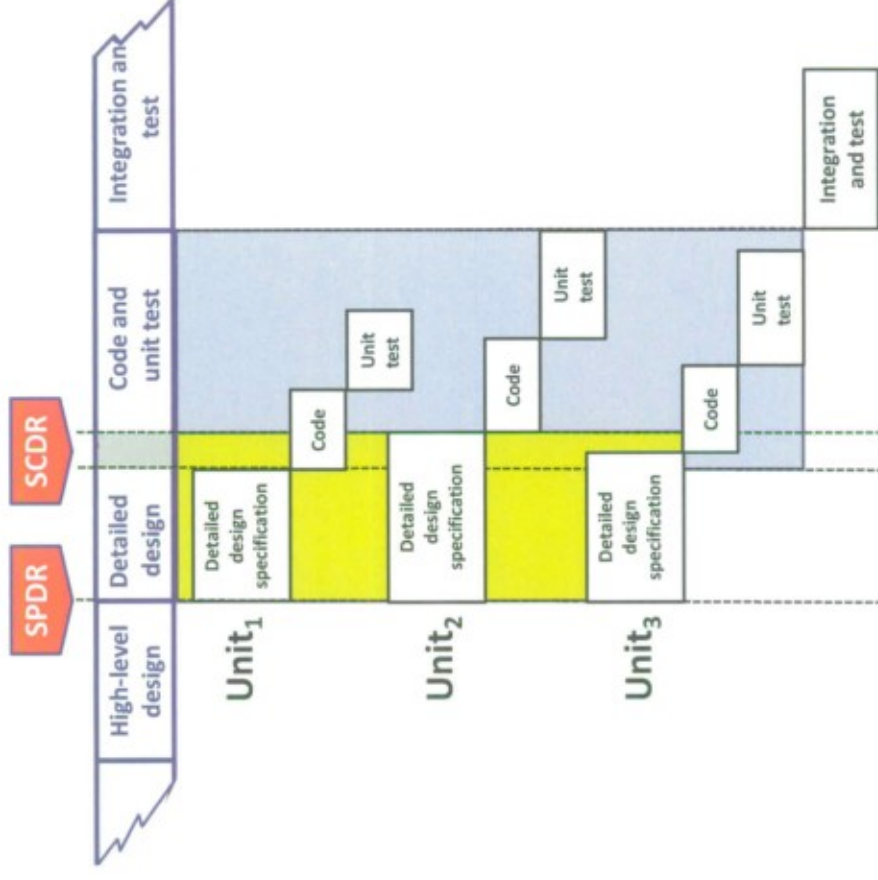
# Selected Name Changes to Clarify the Model's Intent



- Some of the terminology in the original model is outdated or confusing
  - Changes reflect that in this version of the model software is the product
  - New phase and review names now clearly show that they relate to software
  - These clarifications are helpful if we need to place the model in an acquisition or a software-intensive system development context

\* Note that in modern terminology “high-level design” is replaced with “architectural design” and the work product is Software Architecture Description (SAD)

# “Hidden” Concurrency in the Waterfall Model

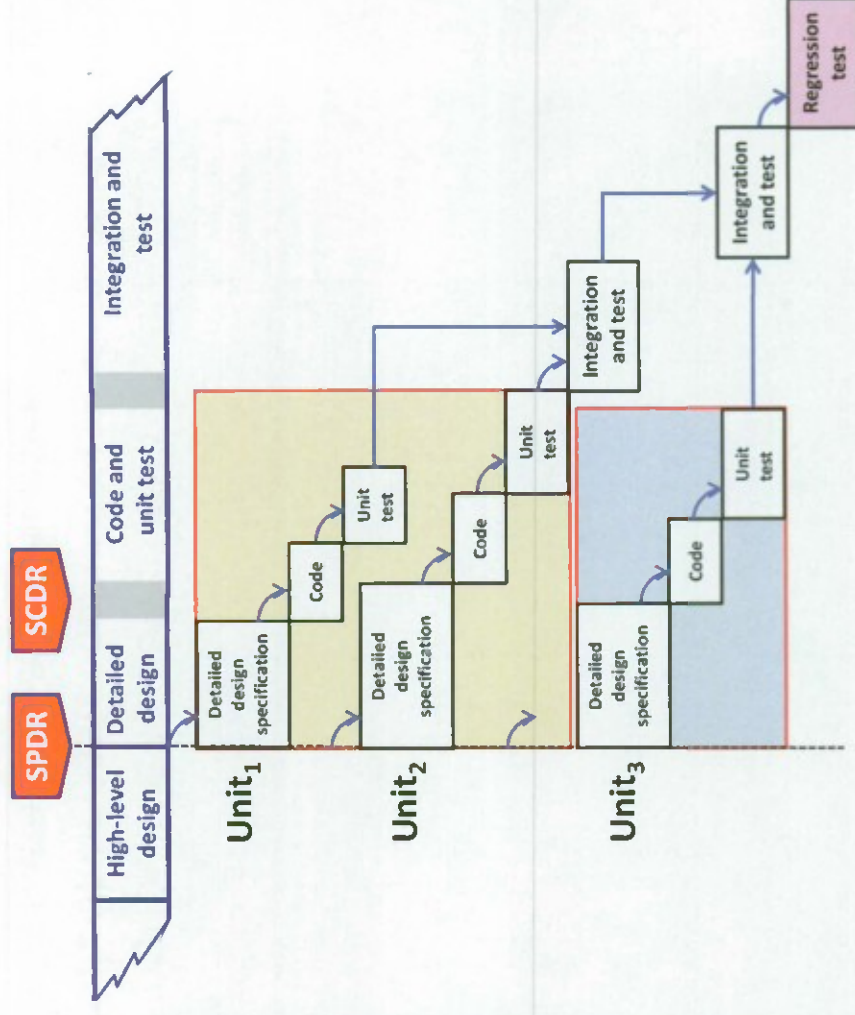


- Unit-level work represents independent and concurrent processes
  - This is where the waterfall is a truly fitting metaphor
  - The streams don't meet before hitting the pool at the bottom
- Note that SCDR positioning and content are ambiguous due to the fact that phase boundaries are now blurred





# Incremental Integration and Pair-wise\* Testing



- This strategy can reduce the problems stemming from belated problem discovery
  - In terms of the metaphor, note the intermediate pools in the picture
  - As a side-effect, phase boundaries are further blurred and the life cycle aspects of the model are less-and-less valid

\* "Pairs" should not be taken literally; multiple units can be integrated as well





# Scaling

- As it was discussed, the model seems to be a macro-model
  - However, the mentioned shortfalls are amplified if the process is indeed executed on the macro level
- Many of the problems can be dealt with if Incremental/Evolutionary strategies are used on the macro-level (including acquisition,) and Waterfall is applied only on lower levels
  - For example, the following strategy hierarchy can be implemented in a space system
    - Acquisition – Once-through (Equivalent of the Waterfall) or Evolutionary
    - System – Incremental Development involving **segments**
    - Segment – Incremental Development involving **elements**
    - Elements – Incremental Development involving **subsystems**
    - Subsystems – Incremental Development involving **software items**
    - Software Items\* – Waterfall Development involving **software units**
- The requirements volatility problem stemming from requirements ambiguity can be mitigated via stronger requirements engineering processes such as prototyping

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\* Larger software Items could be also incremental where each increment is a waterfall



## Some Whimsical Remarks on Requirements

- The Waterfall Model assumes that the requirements can be determined with high-fidelity before actual development starts
  - The mantra in real estate is “Location, location, location”
  - The key to successful software development is “Requirements, requirements, requirements”
- Unfortunately, requirements volatility is a fact of life
  - New, agile methodologies are designed to cope with the influx of new requirements
    - “...we have come to value responding to change over following a plan”\*
  - However, I still suggest listening to Yogi Berra:
    - “If you don’t know where you are going, you will wind up somewhere else”

\* Source: [Agile 2001]



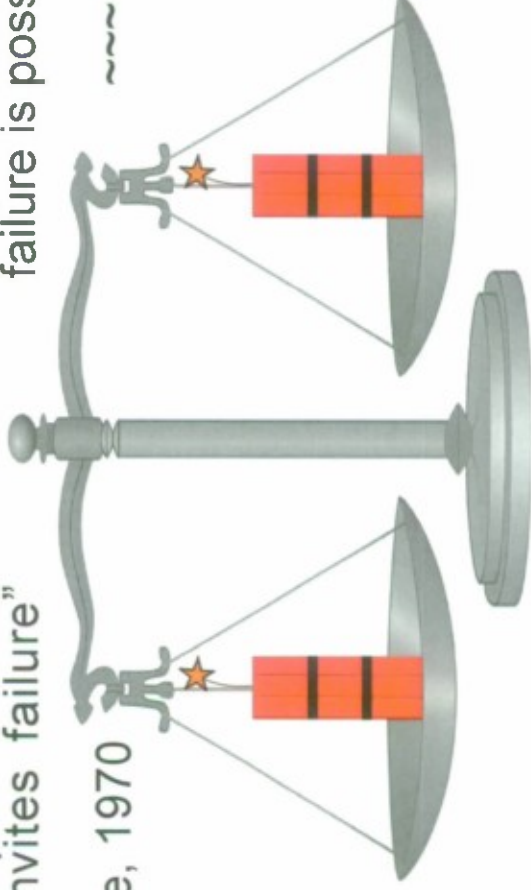
# Conclusion - The Experts' Voice

I believe in this [waterfall] concept, but the implementation ... is risky and invites failure"

~~~ Winston Royce, 1970

"[Iterative development] projects are not easier to set up, to plan, or to control just because they are iterative. The project manager will actually have a more challenging task, especially during his or her first iterative project, and most certainly during the early iterations of that project, when risks are high and early failure is possible."

~~~ Philippe Kruchten, 2000



**Concurrency, scaling, and scope management are equally difficult problems in all methodologies**





## To Get Back to the Mood after the Q/A....

It winds along the face of a cliff  
This path which I long to explore,  
And over it dashes a waterfall,  
And the air is full of the roar  
And the thunderous voice of waters which sweep  
In a silver torrent over some steep.  
It clears the path with a mighty bound  
And tumbles below and away,  
And the trees and the bushes which grow in the rocks  
Are wet with its jeweled spray;

From "A Coloured Print by Shokei," by Amy Lowell



# Acronyms

|             |                                      |
|-------------|--------------------------------------|
| <b>CDR</b>  | Critical Design Review               |
| <b>DBDD</b> | Database Design Description          |
| <b>IDD</b>  | Interface Design Description         |
| <b>IRS</b>  | Interface Requirements Specification |
| <b>PDR</b>  | Product Design Review                |
| <b>SCDR</b> | Software Critical Design Review      |
| <b>SAD</b>  | Software Architecture Description    |
| <b>SDD</b>  | Software Design Description          |
| <b>SDP</b>  | Software Development Plan            |
| <b>SPDR</b> | Software Preliminary Design Review   |
| <b>SRR</b>  | Software Requirements Review         |
| <b>SRS</b>  | Software Requirements Specification  |
| <b>SWRR</b> | Software Requirements Review         |



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(accessed August 24, 2011)

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Poem passage on Slide 18 is courtesy of **themargins.net**:

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